Species

22(70), 2021

To Cite:
Solomon Raju AJ, Purnachandra Rao S, Ch. Prasada Rao. *Sterculia urens* Roxb. (Malvaceae: Sterculiodeae): sexual reproduction and tree death due to traditional gum harvesting practice. *Species*, 2021, 22(70), 323-329

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Peer-Review History
Received: 26 June 2021
Reviewed & Revised: 29/June/2021 to 24/September /2021
Accepted: 26 September 2021
Published: September 2021

Peer-Review Model
External peer-review was done through double-blind method.

Sterculia urens Roxb. (Malvaceae: Sterculiodeae): sexual reproduction and tree death due to traditional gum harvesting practice

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ABSTRACT

Sterculia urens is a deciduous tree species with leaf shedding, flowering and leaf flushing taking place in succession from November to August. It is morphologically andromonoecious but functionally monoecious. Thripsophily is the only pollination system through which fruit set occurs. With limited number of pistillate flowers per tree, ineffective thrips-pollination and nutrient-deficient soil environment collectively contribute to the lowest percentage of fruit set in open-pollinations. Autochory is functional but it is not effective. Gum exuded from the bark of *S. urens* is collected during dry and wet seasons. The gum tapped by following traditional, crude and unscientific method by locals is found to be leading to the death of tapped trees. Therefore, scientific tapping, systematic collection and standardization of harvesting methods are essential to protect trees used for harvesting gum from death.

Key words: *Sterculia urens*, gum karaya, monoecy, thrips, geitonogamy, autochory, unscientific gum harvest.

1. INTRODUCTION

The genus *Sterculia* (Malvaceae-Sterculioideae) consisting of 200 species is widespread throughout the tropical and sub-tropical parts of the world. The species of this genus contain mainly flavonoids but they also contain different chemical constituents in small amounts (El-sherei et al. 2016). Despite the diversity in the number of species and its commercial importance, a very few species have been investigated for their reproductive ecology, the information of which is very essential to understand their sexual system, pollinators and fruiting ecology in order to take measures for the continued availability of the species to use them for commercial purposes. The available information shows that *S. chicha* is monoecious, self-incompatible and sapromyophilous (Taroda, 1982). *S. colorata* is hermaphroditic, self-compatible and

ornithophilous (Solomon Raju et al. 2004). *S. foetida* is morphologically andromonoecious but functionally monoecious due to the function of hermaphroditic flowers as pistillate as a consequence of pollen sterility (Atluri et al. 2004). *S. apetala* is hummingbird pollinated in Colombia (Leon-Carmago and Rangel-Ch, 2015). The sexual system in *S. urens* is variously reported by different authors as andromonoecy, polygamodioecy, monoecy and unisexuality, morphologically andromonoecious but functionally cryptically monoecious (Cooke 1967; Matthew 1983; Ramaswamy and Razi 1973; Bhattacharya and Johri 1998; Verma et al. 1993; Sunnichan et al. 2004). Further, *S. urens* is reported be melittophilous which is effected by the Asiatic honey bee, *Apis cerana* (Sunnichan et al. 2004). In India, *S. urens* is distributed in dry and wet deciduous rocky forests of Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, Gujarat, Orissa, Chattisgarh, Bihar and Rajasthan (Mehta, 1998; Alverson et al. 1999; Bhattacharya et al. 2003; Sunnichan et al. 2004).

Certain plants produce exudate gums which are typically polysaccharides under stress conditions due to physical injury and fungal attack in order to cover injury to the bark to prevent water loss and fungal infection. The dry and hot environment during summer season favours the production of high amount of gum. Further, the gum production is enhanced by making cuts or incisions in the bark. These plants exude gums in small amorphous lumps/mass which form hard and glassy exudates displaying different colours which vary with the each plant species that exudes gum (Sheweta et al. 2020). Commercial exudate gums include gum arabic produced by *Acacia senegal* and *A. seyal* (Fabaceae); gum karaya by *Sterculia urens, S. setigera, S. villosa* (Malvaceae); ghatti gum by *Anogeissus latifolia, A. acuminata, A. bentii* and *A. dhofarica* (Combretaceae); and gum tragacanth by *Astragalus gummifer, A. microcephalus, A. kurdicus* and *A. gossypinus* (Fabaceae) (Verbeken et al. 2003; Sheweta et al. 2020). Among exudate gum yielding species, *S. urens* is highly valued for its gum exuded from its bark. This species is commonly called "Gum Karaya" because of its gum value (Solni, 1995). Various anonymous reports also noted that the gum of this tree species consists of an acetylated polysaccharide containing beta-D-galactose and L-rhamnose sugars, and galacturonic acid. It is used in medicine, cosmetics and foods. The gum from this tree species is over-harvested due to its export value (Sunnichan et al. 2004). In fact, India produces 20,000 tons of exudate gums of which *S. urens* alone contributes about 15,000 tonnes (Yadav and Basera, 2013). It is a livelihood source for poor tribal and rural people, especially during summer season (Sunnichan et al. 2004).

In this paper, we report the ecological aspects of sexual reproduction in *Sterculia urens* and interpret the findings of the study with those of previous studies made by different authors. Further, we also report the harvesting practices employed by locals for the tapping of gum exuded from the bark of *S. urens* and how these practices contribute for the gradual elimination of trees from the study region.

2. MATERIALS AND METHODS

Sterculia urens trees growing in dry and rocky deciduous forest habitats in the surroundings of Punyagiri (18.1097° N, 83.0938° E) which is situated about 60 km away from Visakhapatnam city, Andhra Pradesh, India, were chosen for the study from January 2019 to March 2020 and from December 2020 to April 2021. The trees occur scattered in the forest area (Figure 1a,b). The study was carried out on leaf shedding, flowering, leaf flushing and fruiting aspects in order to understand the phenological and sexual reproduction events. During flowering period, the flower structure and function, sexual system, pollination system, flower foragers, pollination and fruiting ecology were carefully observed. The pollen output per anther and flower were calculated following the standard procedure. The pollen characters, functional aspects and stigma receptivity duration were recorded. Fruit maturation period, fruit and seed characters, fruit/seed dispersal aspects were also noted. Gum exuded from the bark of the trees was found to be collected by local people as a form of livelihood. The gum tapping method followed by them to collect gum was recorded and at the same time whether this method has any impact on the survival of trees was also observed in the field and noted the findings.

3. OBSERVATIONS AND DISCUSSION

Sterculia urens is a deciduous tree species with smooth, fibrous and thick bark, and horizontally-spreading branches. Leaves are simple with 3-5 palmate lobes, hairy on the underside and arranged alternately and clustered at the apical portion of twigs. Leaf shedding occurs during November-January, flowering during February-April with peak phase in March (Figure 1c,d, Figure 2a), and leaf flushing during June-August (Figure 1e). The inflorescence is a panicle densely covered with silky hairs and produced at the terminal portions of the branches (Figure 2b). Each panicle produces exclusively male or both male and bisexual flowers; the male flowers are produced above bisexual flowers which open first at inflorescence level. Both flower sexes are nectar-less and offer pollen as exclusive floral reward for flower foragers.

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Figure 1. *Sterculia urens:* a. Habitat, b. Population cleared for agriculture, c. Flowering initiation, d. Flowering termination, e. Leaf flushing after flowering.

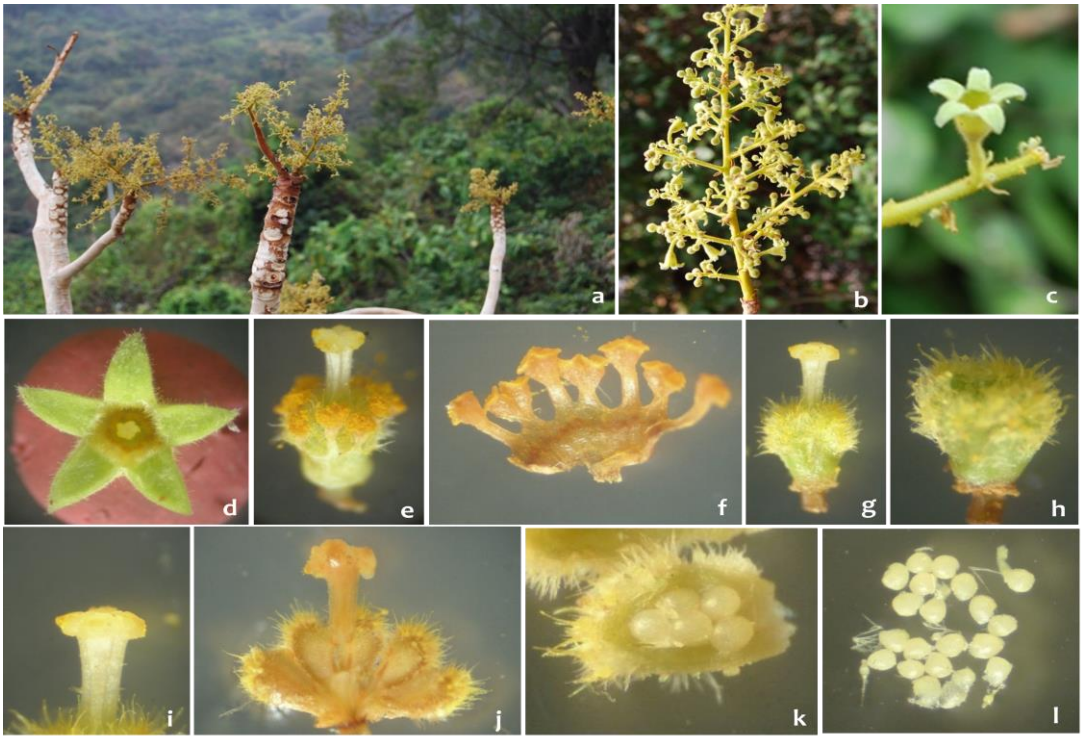

Figure 2. *Sterculia urens:* a. Flowering, b. Inflorescence, c. & d. Bisexual flower, e. Position of stamens and stigma, f. Stamens, g. Pistil, h. Ovary, i. 5-fid stigma, j. Carpels with ovules, k. A carpel with ovules, l. Ovules.

Bisexual flowers

The flowers are pedicellate, small (7.8 ± 0.6 mm long and 7.5 ± 0.5 mm wide), light greenish yellow, foetid smelling, actinomorphic and covered with a combination of stinging and non-stinging hairs (Figure 2c,d). The perianth is cup-shaped and tipped with five light greenish yellow tepals. The corolla is absent. The stamens are 10, light creamy coloured and placed around the carpels; the filaments are 1-2 mm long and bear 1 mm long yellow anthers apically (Figure 2f). The basal portion of filaments is fused forming a staminal sheath enclosing the ovary. The anthers are indehiscent but each anther produces 544.2 ± 113.80 sterile pollen grains. The

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pistil is 3. 7 ± 0.6mm long and consists of 5 free carpelled ovary covered with glandular trichomes and each carpel consists of 6-7 ovules, light cream coloured style and five-lobed wet and shiny stigma (Figure 2g-l); the style and stigma are placed well above the stamens (Figure 2e). The stigma attains receptivity to pollen soon after anthesis and remains receptive on the second day also.

Male flowers

The flowers are pedicellate, small (7.3 ± 0.8 mm, 6.7 ± 0.5 mm), light greenish yellow, foetid smelling, actinomorphic and covered with both stinging and non-stinging hairs (Figure 3a). The perianth is greenish yellow and tubular tipped with five tepals covered with glandular trichomes. Corolla is absent. The stamens are 10 borne on androphore, free, 1-2 mm long; the anthers are golden yellow but lacking filaments (Figure 3b). The flowers open during forenoon period. The anthers are dithecous and dehisce by longitudinal slights soon after anthesis. The pollen grains are sticky, trizonocolporate, 25.4 ± 5.8 µm with a reticulate ornamentation (Figure 3c) and amount to 679.4 ± 115.02 per anther.

Figure 3. *Sterculia urens:* a. Male flower, b. Androphore tipped with stamens, c. Pollen grain, d. & e. Thrips, f-k. Fruit development stages, l. Mature and dry dehisced fruits.

The floral details of *S. urens* indicate that this tree species is morphologically andromonoecious but functionally monoecious because bisexual flowers act as pistillate flowers due to indehiscent anthers and production of sterile pollen grains. Interestingly, the pollen grains characters of both male and bisexual flowers are identical except in function. Further, each flowering tree produces a huge number of male flowers and a few bisexual flowers acting as female sex. The sexual functions of flowers observed in this study conform to the findings by Sunnichan et al. (2004) that *S. urens* displays cryptic monoecy functionally although it produces male and bisexual flowers, the former sex in a large number while the latter sex in a limited number. These authors stated that the anthers in bisexual flowers of *S. urens* serve as attractants to flower foragers. But, in this study, it is found the anthers in bisexual flowers are located far below the style and stigma and hence flower foragers cannot perceive the presence of forage from a long distance unless and until they land and probe the flower. However, the anthers of male flowers being yellow in colour and placed slightly above the rim of calyx could serve as attractants to flower attractants. Sunnichan et al. (2004) also mentioned that the pistillate flowers of *S. urens* exhibit self-incompatibility and it is expressed only when the pollen tube finds its way into the ovule for fusion. The present study shows that thrips use *S. urens* flower buds as breeding sites and also as feeding station during mature bud and open state of flowers. Both male and bisexual flowers offer only pollen as floral reward. The thrips in huge numbers make movements within and between inflorescences of the same tree irrespective of the sex of the flower to collect pollen and in this process, they transfer pollen from male flowers to bisexual flowers effecting self-pollination (geitonogamy) (Figure 3d,e). But, thrips could get pollen from only male flowers but not from bisexual flowers due to indehiscent nature of the anthers (Sunnichan et al. 2004). In this study, it is found that *S. urens* flowers do not produce nectar. Other workers (Vogel, 2000; Sunnichan et al. 2004) also mentioned that *S. urens* flowers are nectar-less. Sunnichan et al. (2004) reported that *S. urens* is

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS

pollinated by the honey bee, *Apis cerana* and wind has no role in pollination. In this study also, it is found that there is no possibility for wind pollination because the pollen is sticky and oily due to the presence of lipids. Further, honey bees never visited the flowers although they are present in biotope of the study area indicating that *S. urens* is not a floral resource for honey bees. Therefore, *S. urens* is functionally monoecious and pollinated exclusively by thrips.

Fruiting

Flowers begin fruit development as soon as they fertilized. But, fruits grow very slowly during dry season but speed up their growth following the completion of leaf flushing event. They gradually mature within 5-6 weeks and become dry during late winter and early dry season. In initial stages of fruit growth, the fruit wall is velvety and profusely covered with soft, reddish to magenta coloured trichomes and the fruit wall colour gradually turns green later (Figure 3f-k). The fruits are star-shaped at maturity due to spreading of follicles which are the products of free carpels; at this stage, the follicles are ovoid, oblong, 6.2- 7.2 cm long, 2.5- 2.8 cm in diameter and covered with hard and stiff trichomes. Each follicle produces 3 to 6 oblong and light black seeds. Fruits a follicle type, dehiscent and self-dispersal occurs by autochory (Figure 3l). But, autochory is not effective as many seeds remain within the fruit even after dehiscence.

Sunnichan et al. (2004) reported that in *S. urens*, fruit set in open pollinations stands at 0.7-3.2% only. The present study found that individual trees produce 5-10 follicular fruits indicating very low fruit set rate in open-pollinations, which is attributable to the inefficient geitonogamous pollinations carried out by thrips, production of a few bisexual flowers and nutrient resource constraints due to dry and rocky lands. Field study indicated that there is no year to year recruitment due to very low fruit set rate and lack of seed germination because of lack of optimal soil conditions in the rocky terrain. In this context, it is pertinent to state the report by Subhashini Devi et al. (2012) that in *S. urens*, all fresh seeds germinate under optimal soil conditions and they display both physical and chemical dormancy; the former can be overcome by using acid and mechanical scarification while the latter by treating seeds with phytohormone Gibberellic Acid (Subhashini Devi et al. 2012). Therefore, *S. urens* is experiencing recruitment problems from seed mode; there is a need to opt for micro-propagation techniques in order to populate the natural habitats as well as other habitats where its seedlings are able to establish and produce new trees.

Figure 4. *Sterculia urens:* a. Trunk before cut, b. Local person peeling the bark for gum extraction, c. & d. Gum exudation from cut part within 2-3 days, e. & f. The cut part after extraction of gum, g. First grade gum, h. Second grade gum, i. Third grade gum.

Gum harvesting practices:

Sterculia urens is a highly valued tree species for its gum which exudes from its bark. It is used for different purposes in the preparations of food, medicinal dental and industrial products (Solni, 1995). It also has export value due to which this product is over-harvested and is a valuable livelihood source for poor tribals and rural people (Sunnichan et al. 2004). The commercial and

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS

economic values associated with the gum of *S. urens* are driving the locals to over-harvest this product in the study area. This tree species is also included as a source of an essential product in the list Non-wood forest products collected/procured from the Eastern Ghats forests of Andhra Pradesh. The harvesting of gum from the bark of the tree is done unscientifically. The bark is stripped off from the trunk and by making deep cuts near the trunk base by using a sickle to create injury or wound. Gum begins to exude from the tree as irregular lumps/masses within 2-3 days (Figure 4a-f). Its exudation is more during hot and dry summer season as it enhances stress conditions. The gum is graded according to viscosity and color; white coloured gum is the best grade while the other coloured gums are of low quality (Figure 4g-i). Accordingly, the price of the grade is fixed. The gum exuded during summer season is of high quality while that exuded during wet season is of inferior in quality. This form of gum collection is a traditional crude unscientific method due to which the trees subjected to gum harvest die in course of time and in fact many trees disappeared in the study area. An anonymous report states that the plant growth regulator "ethephon" when used in controlled quantities invigorates gum production, gum yield increase and promotes wound healing and tree survival. Old trees death and absence of recruitment of new seedlings in the natural habitats are contributing to the large-scale eradication of populations of *S. urens*. Therefore, scientific tapping, systematic collection and standardization of harvesting methods are inevitable to enhance the production of exudate gum and protect the tapped trees from death.

4. CONCLUSIONS

Sterculia urens is a commercial important deciduous tree species. The gum exuded from its bark is highly valuable and also has export value. Leaf shedding, flowering and leaf flushing occur in succession from November to August. Fruiting initiation occurs soon after fertilization of flowers and the fruits begin to mature for dehiscence and dispersal during early to late dry season. Individual trees produce both male and bisexual flowers either on the same or different inflorescences but bisexual flowers are functionally pistillate (female) since the anthers in these flowers are indehiscent and the pollen produced by them is sterile. The pollen in male flowers is sticky and oily and hence anemophily is ruled out. Insect species despite their presence in the habitat never attempted to visit the flowers of both male and pistillate flowers indicating that the flowers are not attractive and not appropriate for their visits. Further, both flower sexes lack nectar. Thrips use flower buds for brood provisioning while maturing buds and flowers for pollen feeding. Their pollen feeding activity is confined to the same tree on which they occur. They are short-distance fliers and cannot fly to other distantly spaced conspecific trees to collect pollen. As a consequence, they contribute to only geitonogamy. With limited number of pistillate flowers per tree, ineffective geitonogamy and resource constraint soil environment collectively contribute to the evidenced percentage of fruit set in open-pollinations. Autochory is functional but it is not effective. Seed germination and seedling recruitment have not been found in the habitat of *S. urens*.

Gum exuded from the bark of *S. urens* is collected during dry season as well as wet season. But, gum harvested during dry season is of high quality compared to that harvested during wet season. The gum is tapped by following traditional, crude and unscientific method by locals. As a result, the tapped trees with deep gashes are dying eventually. Therefore, scientific tapping, systematic collection and standardization of harvesting methods are essential to protect trees used for harvesting gum from death.

Acknowledgements

We thank the Andhra University, Visakhapatnam, for providing basic facilities to carry out this piece of research work.

Authors contributions

All authors contributed equally.

Funding:

This research received no external funding.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study for species collection & identification.

Conflicts of interest:

The authors declare no conflict of interest.

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Alverson, W.S., Whitlock, B.A., Nyffeler, R., Bayer, C. and Baum, D.A. 1999. Phylogeny of the core Malvales: evidence from ndhF sequence data. Am. J. Bot. 86: 1474-1486.
2. Atluri, J.B., Ramana, S.P.V. and Reddi, C.S. 2004. Sexual system and pollination of *Sterculia foetida* Linn. Beitrage zur Biologie der Pflanzen 73: 223-242.
3. Bhattacharya, B. and Johri, B.M. 1998. Flowering plants: taxonomy and phylogeny. Narosa Publishing House, New Delhi.
4. Bhattacharya, P., Joshi, B. And Hayat, S.F. 2003. An improved method of tapping gum from kullu Sterculia urens. Forests, Trees and Livelihoods 13: 187-196.
5. Cooke, T. 1967. Pollen-pistil interactions during pollen tube growth. Trends Plant Sci. Rev. 1: 45-51.
6. El-sherei, M.M., Ragheb, A.Y., Kassem, M.E., Marzouk, M.M., Mosharrafa, S.A. and Saleh, N.A.M. 2016. Phytochemistry, biological activities and economical uses of the genus Sterculia and the related genera: a review. Asian Pac. J. Trop. Dis. 6: 492-501.
7. Leon-Carmago, D. And Rangel-Ch, J.O. 2015. Interaccion colibri-flor en tres remanentes de bosque tropical seco (BST) del municipio de Chimichagua (Cesar, Colombia). Caldasia 37: 107-123.
8. Matthew, K.M. 1983. The Flora of the Tamil Nadu Carnatic Vol. II. The Rapinat Herbarium. Thiruchirapalli, India.
9. Mehta, A.K. 1998. Administrative responsiveness and competitiveness: Gum Karaya Case. Indian J. Public Admn. 44: 157-165.
10. Ramaswamy, S.V. and Razi, B. 1973. Flora of Bangalore district. Prasararanga, University of Mysore, India.
11. Sheweta, B., Deepak, M. and Shelly, T. 2020. Exudate gums: chemistry, properties and food applications – review. J. Sci. Food Agric. 100: 2828-2835.
12. Solni, P.L. 1995. Some commercially important Indian gum exudates. Indian Forest. 121: 757-759.
13. Solomon Raju, A.J., Purnachandra Rao, P. and Ezradanam, V. 2004. Bird-pollination in *Sterculia colorata* Roxb. (Sterculiaceae), a rare tree species in the Eastern Ghats of Visakhapatnam and East Godavari Districts of Andhra Pradesh. Curr. Sci. 87: 28-31.
14. Subhashini Devi, P., Satyanarayana, B., Arundhati, A. And Raghava Rao, T. 2012. Effect of storage temperature and dormancy-breaking treatments on seed germination, moisture content and seed vigor in gum karaya (*Sterculia urens* Roxb.). Forest Sci. and Tech. 8: 11-15.
15. Sunnichan, V.G., Mohan Ram, H.Y. and Shivanna, K.R. 2004. Floral sexuality and breeding system in gum karaya tree, *Sterculia urens*. Plant Syst. Evol. 244: 201-218.
16. Taroda, N. 1982. Floral biology and breeding system of Sterculia chicha St. Hil. (Sterculiaceae). New Phytol. 90: 735-743.
17. Verbeken, D., Dierckx, S. And Dewettinck, K. 2003. Exudate gums: occurrence, production, and applications. Appl. Microbiol. Biotechnol. 63: 10-21.
18. Verma, D.M., Balakrishnan, N.P. and Dixit, R.D. 1993. Flora of Madhya Pradesh Vol. 1. Botanical Survey of India, Calcutta.
19. Vogel, S. 2000. The floral nectaries of Malvaceae sensu lato - a conspectus. Kurtziana 28: 155-171.
20. Yadav, M. and Basera, K. 2013. Status of forest products production and trade. Working Paper Series (2013/1) Centre for Sustainable Forest Management and Forest Certification, Indian Institute of Forest Management, Bhopal.

ISSN 2319–5746 EISSN 2319–5754 I OPEN ACCESS